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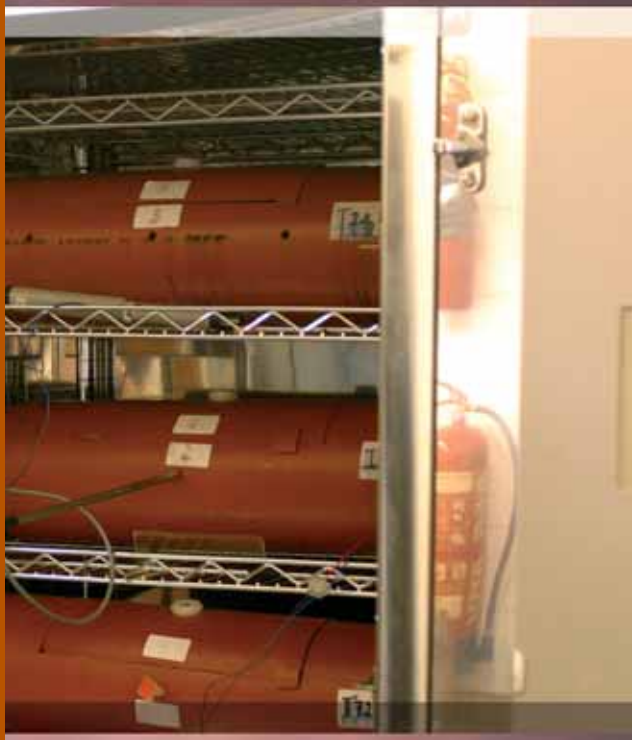
A study on the use of chilling as a critical control point in a beef HACCP plan



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RESEARCH REPORT

A STUDY ON THE USE OF CHILLING AS A CRITICAL CONTROL POINT IN A BEEF HACCP PLAN

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SUMMARY

Investigations were undertaken to establish the critical limits for use of chilling in a Hazard Analysis Critical Control Point (HACCP) system for beef. Information was obtained on the influence of chilling on the survival of bacteria, including the pathogen *Salmonella* Typhimurium DT104, attached to beef carcass surfaces. In general, a chilling regime could not be identified that gave consistent and meaningful reductions in surface bacterial counts while not seriously compromising the quality of the carcasses in terms of excessive amounts of weight loss. The study concluded that chilling was not a satisfactory process for use as a critical control point (CCP) in beef chilling and could not be recommended to the Irish beef industry for inclusion in a HACCP plan.

INTRODUCTION

The Hazard Analysis Critical Control Point (HACCP) system is universally recognised and accepted for food safety assurance. HACCP is a systematic means of controlling any hazard [physical, chemical or microbiological] that may arise in a food processing operation. It is a preventative control system wherein hazards are identified, critical control points (CCPs) are determined and the methods for control and compliance are clearly specified.

At present, there is some confusion and conflicting data as to the use of chilling as a CCP (Gill and Bryant, 1997; Nutsch *et al.*, 1997 and McEvoy *et al.*, 2000). These data prompted the investigations reported here, which were aimed at defining the precise refrigeration conditions that would give consistent and significant reductions in bacterial counts.

There is general agreement that carcass chilling controls bacterial growth via extrinsic and intrinsic factors. The extrinsic factors are temperature, relative humidity (RH) and air speed and the intrinsic factor is water activity (a_w) (Nottingham, 1982). It is suggested that osmotic and low temperature stresses act synergistically to kill bacterial cells on beef carcasses during

chilling. The effect of these stresses on the natural microflora and on artificially inoculated *S.* Typhimurium DT104 on beef was investigated in this study. *S.* Typhimurium is one of the most common *Salmonella* serotypes infecting cattle (Ekperigin and Nagaraja, 1998).

OBJECTIVE OF THE STUDY

The aim of the study was to determine the influence of chilling on pathogen survival and on the normal microflora on beef carcass surfaces and, from this, to establish the critical limits for use of chilling as a CCP in beef HACCP. The first study described demonstrates the effect of both spray- and conventional chilling in a commercial setting on the natural beef microflora. The final two studies investigated the effects of various temperature and RH combinations on the survival of *S.* Typhimurium DT104 and on the natural microflora on beef carcass surfaces.

EFFECT OF SPRAY-CHILLING ON BEEF MICROFLORA

The commercial abattoir used for this study slaughtered cattle at a line speed of 40 – 60 animals per hour, with carcass sides being placed in chill units between 25 and 35 mins after slaughter and dressing. Beef carcass sides (n=30) were placed in chill units fitted with the spray system (spray cycle 2 mins on, 1 min off for 15 h). The system sprayed finely atomised water into the air within the chill unit with the aim of increasing the RH within the chill and reducing the extent of carcass weight loss. Immediately after dressing, and after 24 h in the chill unit, the surface water activity and the weight of each side were measured, and 5 cm^2 samples were recovered from four locations, i.e. rump, flank, brisket and neck on the surface of each side. These samples, and similar samples from control sides (n=30) processed in the standard commercial unit (without spraying), were subjected to microbiological examination by direct counts on plate count agar [Total viable counts (TVCs)], MacConkey agar [coliforms] and violet red bile glucose agar [*Enterobacteriaceae*].

No significant differences were observed between sprayed and control sides for any of the bacterial groups investigated (Table 1 shows data for TVCs). After 24 h in chill units, sprayed sides exhibited an average weight loss of 1.36%, which is significantly less ($P<0.001$) than the average weight loss (1.55%) from control sides.

These results indicate that the spray-chilling system used in the chills in this abattoir could reduce carcass weight loss (on average by 0.19%) without significantly increasing bacterial numbers.

Table 1. Total viable counts (log_{10} cfu cm^{-2}) from sites on beef carcasses before and after chilling

Type of chilling	Stage of chilling	Rump		Flank		Brisket		Neck	
		xa	sb	x	s	x	s	x	s
Spray	Pre-chill	3.02	0.76	3.03	0.89	2.92	0.74	2.11	1.28
	Post-chill	1.94	1.01	1.30	0.97	0.83	1.10	0.56	1.17
Control	Pre-chill	2.97	0.96	2.00	1.26	2.83	0.86	1.70	1.54
	Post-chill	2.52	1.30	1.67	0.91	1.15	1.11	1.19	1.11

[a]mean log $_{10}$ cfu cm^{-2}

[b]standard deviation

SURVIVAL OF *S.* TYPHIMURIUM DT104 ON BEEF SURFACES

The aim of this work was to measure pathogen survival on beef carcass surfaces under experimental conditions of temperature, RH and air speed similar to those encountered in a commercial chilling operation and also under abuse conditions e.g. 10°C. This study was carried out using an environmental chamber (Figure 1) in which the temperature and RH of the

air were maintained at the conditions set by the operator via the control system. Beef carcass surfaces (lean cut-surface, adipose and lean with intact fascia) were inoculated with *S.* Typhimurium DT104 and placed in wind tunnels. The tunnels were designed with a fan at one end to allow the airflow to pass over the upper beef surfaces at 0.5 m s^{-1}. The tunnels were placed in the environmental chamber set at the required RH (75 and 96%) and temperature (5 and 10°C). Water activity measurements and microbiological examination [by direct plating onto xylose lysine desoxycholate agar (XLD)] of the meat samples were determined at 0, 24, 48 and 72 h.

Figure 1. A) Wind-tunnel with sample ports and B) Location of samples within the wind tunnel.

Generally, no change in *S.* Typhimurium DT104 counts were observed after 24 h on all three beef surfaces at both temperatures and RHs (Table 2). Significant reductions ($P<0.01$) were noted at the lower RH of 75% after 48 and 72 h on all three surfaces and at both temperatures. Specifically, pathogen counts decreased by almost one log unit or greater after 72 h. Lean and adipose samples showed the lowest counts after 72 h at 5 °C (1.26 $\log_{10}$ cfu cm^{-2}). The higher RH of 96% resulted in increased counts ($P<0.05$) after 72 h on all beef surface types at 10°C.

It appears that, in all cases, the chilling regimes used were ineffective in reducing *Salmonella* numbers on beef carcass surfaces after 24 h. In general, the maximum chilling time for beef carcasses under commercial conditions is

Table 2. The effect of RH, temperature and time on the survival of *S.* Typhimurium DT104 (log_{10} cfu cm^{-2}) inoculated on beef carcass surfaces

Surfaces	RH (%)	5°C				10°C			
		0h	24h	48h	72h	0h	24h	48h	72h
Lean	75	2.78	2.59	1.97	1.26	2.87	2.68	2.10	1.74
	96	2.80	2.73	2.58	2.72	2.53	2.33	2.47	3.10
Adipose	75	2.49	2.25	1.85	1.26	2.70	2.05	1.72	1.40
	96	2.49	2.42	2.30	2.36	2.09	2.27	3.26	3.41
Fascia	75	2.80	2.75	1.88	1.71	2.82	2.67	2.08	1.82
	96	2.62	2.71	2.66	2.80	2.45	2.30	2.29	2.72

24 h. It may be that extending the chill time beyond 24 h would give beneficial reductions in counts under conditions of low RH but, in production terms, because of increased weight loss and storage capacity problems, this option is unsatisfactory.

INFLUENCE OF CHILLING ON TVCs ON BEEF SURFACES

This work was carried out in the on-site abattoir at Ashtown Food Research Centre. The RH and temperature of the chill unit were varied to determine their influence on reductions in the surface flora of beef carcasses. Two animals were slaughtered weekly (24 in total) and, following dressing, carcasses were placed in the experimental chill unit and subjected to one of four chilling regimes for 72 h. The tested regimes were as follows: combinations of 3°C with 78 or 90% RH and 9°C with 78 or 90% RH. Sampling for microbiological testing was carried out immediately after dressing (pre-chill samples) and at 24, 48 and 72 h post-chilling. Four sites (rump, flank, brisket and neck) were investigated. TVCs were recovered by

direct plating onto plate count agar (PCA) and incubating the plates at 25°C for 72h. Samples from the four sites were obtained also for a_w measurements.

Table 3 shows the effect of RH, temperature, carcass site and time on TVCs during 72 h. In general, no change in counts occurred after 24 h at any site during any of the chilling regimes tested. After 48 and 72 h chilling, TVCs increased ($P<0.05$) at the higher RH and temperature combination. The a_w values ranged between 0.945 and 0.994 across all sites at time zero and between 0.957 and 0.987 after 24 h under the four conditions.

Currently, TVCs are used as a measure of the hygiene status of beef carcasses in Irish abattoirs. Other studies carried out in Ashtown Food Research Centre also demonstrated no change in surface counts after 24 h chilling; however, reductions were achievable and maximal between 24 and 48h.

These experiments were designed to determine the influence of temperature and surface a_w on the reduction in bacterial counts on beef carcasses. It was anticipated that the RH levels used would result in correspondingly high and low carcass surface a_w values. However, the results clearly indicate that the surface a_w values undergo very small changes over time and that a_w is unlikely to influence the survival of bacteria on beef carcass surfaces to the extent that temperature does. The lack of response of meat surfaces to changing chill RH has been noted previously during these investigations. The reason for this lack of response may be related to the ability of the meat to continuously replace the water being lost from the carcass surface.

CONCLUSIONS

- The spray-chilling system offered a small advantage in weight loss savings compared to conventional chilling without significantly increasing bacterial numbers on beef surfaces.

Table 3. Effect of RH, temperature, carcass site and time on TVCs (log_{10} cfu cm^{-2})

RH (%)	Temp. (^{0}C)	Site	Time (h)			
			0	24	48	72
78	3	Rump	0.70	1.90	1.31	1.93
		Flank	1.68	1.95	2.03	1.55
		Brisket	1.61	1.86	2.72	2.33
		Neck	1.41	1.94	2.11	2.17
	9	Rump	2.31	2.32	2.11	2.83
		Flank	2.07	2.12	2.51	2.36
		Brisket	1.72	1.99	1.56	1.84
		Neck	1.86	1.74	1.79	2.83
90	3	Rump	2.61	2.37	2.16	2.04
		Flank	1.32	2.15	2.17	2.04
		Brisket	1.14	2.19	1.83	1.90
		Neck	1.52	1.33	1.26	1.20
	9	Rump	2.45	2.27	3.65	4.03
		Flank	1.61	2.01	4.20	5.04
		Brisket	1.83	2.65	3.48	4.12
		Neck	2.04	2.89	4.02	5.29

- The chilling regimes tested were ineffective in reducing *S.* Typhimurium DT104 counts and TVCs on beef carcass surfaces within 24 h.

- The RH of the chill did not have a significant effect on bacterial survival and carcass surface a_w is unlikely to be a major factor in reducing carcass surface counts.

RECOMMENDATIONS TO INDUSTRY

The most important observation arising from this study is that chilling is not a process that can be relied upon to give consistent and significant reductions in contamination levels, as would be expected for a critical control point in a HACCP plan for fresh meat slaughter. Even in defined chilling conditions, where a reduction in surface counts could be consistently demonstrated, this would conceal the fact that significant numbers of cells were injured but viable and the observed reductions were not related to cell death.

In the future it would seem worthwhile to assess the contribution of individual interventions (organic acid sprays; hot water or steam pasteurisation etc) in different combinations. In these circumstances, bacterial cells would succumb to the additional stress from chilling. It could be that a combination of the more effective interventions could be as beneficial as using all interventions.

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